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PASSIVE TOBACCO SMOKE INHALATION AND LUNG FUNCTION IN ADULTS

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ABSTRACT

To find an answer to the question, whether passive inhalation of tobacco smoke may cause a reduction of lung function, an investigation involving 1,364 white collar workers with healthy lungs was carried out. The group was divided into never smokers, passive smokers, ex-smokers, and current smokers. Lung function was tested by measuring the flow-volume curve standardized for age, height and body weight. Our findings confirmed, as expected, that active smoking causes an impairment of pulmonary function. Ex-smokers and passive smokers showed no flow reductions, which were out of the range of the normal variability. From this it follows that average everyday passive smoke exposure in the office or at home does not lead to essential impairments of lung function in healthy adults.

INTRODUCTION

There is no doubt that active inhalation of tobacco smoke can cause a reduction in pulmonary function. This applies both to the ventilation with decreased forced expiratory vital capacity (FVC) and to forced expiratory volume in one second (FEV_1) (4, 14, 22, 26, 30, 49, 51, 55). Furthermore obstructions of the small airways have been discovered in active smokers by other authors using end-expiratory flows of the flow-volume (MEFV)-curve (4, 9, 16, 29, 37, 44).

Our knowledge of the effects of passive smoking on the bronchopulmonary system, however, is still far from being complete (Surveys in 2, 3, 15, 17, 21, 28, 32, 34, 35, 52, 57).

Studies in children are of particular interest because developing lungs may be more sensitive to the effects of environmental tobacco smoke. Therefore until now already 24 epidemiologic research papers have been published on the effects of current or life-time parental smoking on pulmunary function in children.

Some studies demonstrate a significant negative effect of parental smoking (e.g. 47, 48, 50, 56, 61), other results are inconsistent (e.g. 18, 53, 54) and a number of investigations fail to find any associations between parental smoking habits and a decreased pulmonary function in their children (e.g. 13, 33, 42, 46). These inconsistencies may depend on misclassification bias, socioeconomic status, outdoor air quality, home heating, air conditioning and humidity, genetic factors and in utero or lactational mechanisms by maternal smoking (survey in 62).

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In persons with bronchopulmonary prior diseases, i.e. bronchial hyperreactivity, chronic bronchitis or asthma, passive smoking can either aggravate or lead to a relapse of the illness as is reported in some studies (12, 41, 45, 59). Other authors such as Lebowitz (31), did not find these effects.

In view of these partly contradictory findings the question arises to what extend passive smoking can impair lung function in healthy adults. Only a few studies have dealt with this question and their results are not uniform. To obtain a better insight into this issue, we carried out a study involving a larger group of white collar workers in 1982 - 1983 (27). While our evaluation at that time concentrated on the time-volume curve, our attention is focussed at present on the flow-volume curve.

PATIENTS AND METHODS

A total of 1,351 subjects (951 men and 413 women) took part in the study. All of them were office workers and participated voluntarily under blind study conditions. The subjects filled out a standardized questionnaire containing among other questions regarding their smoking habits and bronchopulmonary prior diseases.

Subsequently the overall group was divided into four subgroups:

- Never smokers (NS), defined as persons who have never been regularly exposed to tobacco smoke, either actively or passively.
- Passive smokers (PS), defined as subjects who have never actively smoked, but who are currently exposed to passive smoking.
- Ex-smokers (ES), defined as persons who had given up active smoking at least six months previously.
- Current smokers (CS) representing the group of persons who, at the time of the investigation were actively smoking cigarettes, cigars or pipes.

The size of the subgroups, sex ratios, average age and prior diseases in the lower respiratory system are specified in tab. 1.

As statistical analysis of associations between lung function in healthy subjects and persons with prior diseases such as pneumonia, asthma, tuberculosis of the lungs and chronic bronchitis showed no significant differences, subjects with prior illnesses were not excluded.

	No. of subjects examined		Age in years (median values)		Bronchopulmonary prior diseases (pneumonia, asthma, tuberc. of the lungs)		Chronic bronchitis	
	M	F	M	F	M	F	M	F
NS	146	66	42 (31-51)	41 (33-55)	21	7	3	2
PS	252	133	39 (28-52)	37 (23-51)	30	18	8	3
ES	301	60	45 (34-55)	39 (26-49)	42	8	9	3
CS	252	154	40 (30-53)	31 (22-43)	34	13	10	8
Su.	951	413	41 (31-53)	35 (26-50)	127	46	30	16

Tab. 1: Number of subjects examined, average age and bronchopulmonary prior diseases in the subgroups.

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Lung functions tests were carried out using an electronic spirometer with a so-called spiroceptor[1]. Test subjects remained in a sitting position for the breathing exercises. The flow-volume curves were recorded by a xy-recorder[2] under BTPS-conditions.

Generally the respiration manoeuvres were repeated two to three times, with only the best curve (plausible figure, maximal values) being used for evaluation.

The following parameters were determined from the flow-volume curve:
- Forced expiratory vital capacity (FVC),
- peak expiratory flow (PEF) with the additional volume (PEF-V),
- maximal expiratory flows at 75, 50, 25 and 15 % of the remaining FVC (MEF 75, MEF 50, MEF 25, MEF 15).

		AGE (YEARS)	HEIGHT (M)	WEIGHT (KG)	CONST.
FVC	M	- 0.026	5.766	- 0.007	- 3.633
	F	- 0.029	4.493	- 0.008	- 2.220
PEF	M	- 0.021	8.410	- 0.040	- 2.221
	F	- 0.057	4.234	0.041	- 1.375
PEF-V	M	- 0.008	0.157	- 0.001	- 0.883
	F	0.003	0.134	- 0.003	- 0.541
MEF 25	M	- 0.021	5.854	- 0.039	1.015
	F	- 0.054	3.733	0.027	- 0.209
MEF 50	M	- 0.019	4.203	- 0.023	- 0.054
	F	- 0.049	2.398	0.020	0.578
MEF 75	M	- 0.015	2.345	- 0.010	- 0.973
	F	- 0.031	1.890	- 0.003	- 0.215
MEF 15	M	- 0.007	1.226	- 0.005	- 0.599
	F	- 0.023	2.071	- 0.005	- 1.418

Tab. 2: Correlation factors for adjustment of the pulmonary functio parameters

Normal values were determined for these parameters on the basis of the measurements obtained in the never-smoker group. For this multiple regression analysis was used by adjustment for sex, age, height and weight (tab. 2). The confidence interval of standardized normal values for each subgroup is shown cross-hatched in fig. 1 - 4.

The difference between real and nominal values was analyzed statistically by a matched pairs signed rank test (60). Statistical significances are marked with one ($p = 0.05$) or two asteriks ($p = 0,01$), resp. (fig. 1 - 4).

RESULTS AND DISCUSSION

Current smokers

The findings of our study support the thesis, mentioned in the introduction, that active inhalation of tobacco smoke leads to impairments of pulmonary function. A decrease in MEF 50, MEF 25, MEF 15 and FVC was found in male CS. Female CS even showed a degradation in all parameters (fig. 1).

1) Siregnost FD 10, Fa. Siemens, Erlangen, FRG
2) xy-Recorder E 2218, Fa. Siemens, Erlangen, FRG

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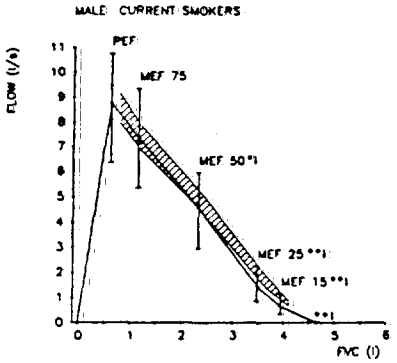


Fig. 1: MEFV-curves in male and female current smokers

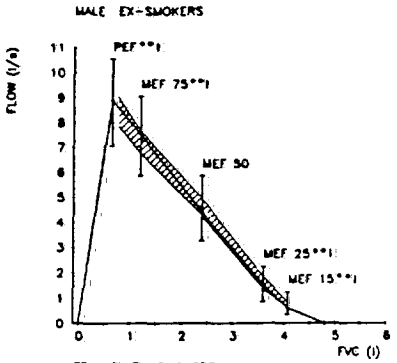
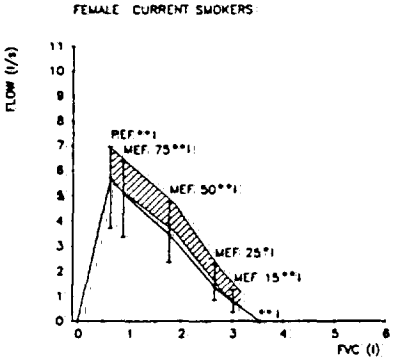
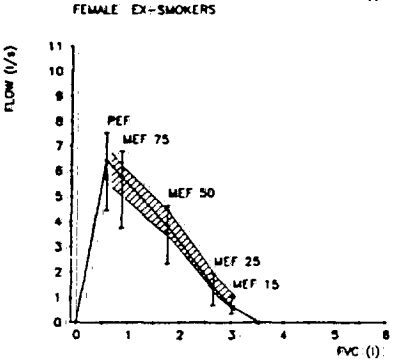


Fig. 2: MEFV-curves in male and female ex-smokers





This means that in men the effect of tobacco smoke inhalation is predominantly reflected in a small airways dysfunction, whereas in women active inhalation shows more severe effects (36). The depression of the entire flow-volume curve in female CS indicates more central bronchial obstructions (25).

The fact that women consume fewer cigarettes than men and also spend a shorter period as smokers shows the particular health hazard in women. While women reach 6.7 packyears (20 cig./day), men have a consumption of 16.6 packyears (tab. 3).

Ex-smokers

We found no essential worsening of lung function in ex-smokers either in men or in women (fig. 2). The only exception here is the decrease in MEF 25 and MEF 15 in men. On the other hand, PEF and MEF 75 in male ES show an increase.

Mean ex-smoker period in men was 7.0 years and in women 4.5 years (tab. 2). Apparently during that time a restitutio ad integrum occurs, also in women, although the impairment of their lung function due to active smoking is more pronounced than in men. Similar results have been obtained

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		Cigarettes/day	Smoker years	Pack years	Ex-smoker years
ES	M	20.0 (9.0-37.5)	15.0 (7.5-22.5)	15.0 (3.5-42.0)	7.0 (1.5-12.5)
	F	14.0 (5.5-22.5)	9.5 (2.5-18.0)	6.3 (0.5-20.5)	4.5 (1.0- 9.5)
CS	M	19.0 (1.0-29.0)	17.5 (8.5-29.0)	16.6 (0.2-42.0)	-
	F	14.5 (6.5-24.0)	9.5 (4.5-19.0)	6.7 (1.5-22.8)	-

Tab. 3: Smoking habits in ex-smokers and current smokers (median values and 66 2/3 confidence intervals).

in intervention studies (5, 7, 8). For example Buist et al. (8), by measuring lung function standard parameters, demonstrated a clear improvement in ventilation after smoking cessation within a period of six to seven months.

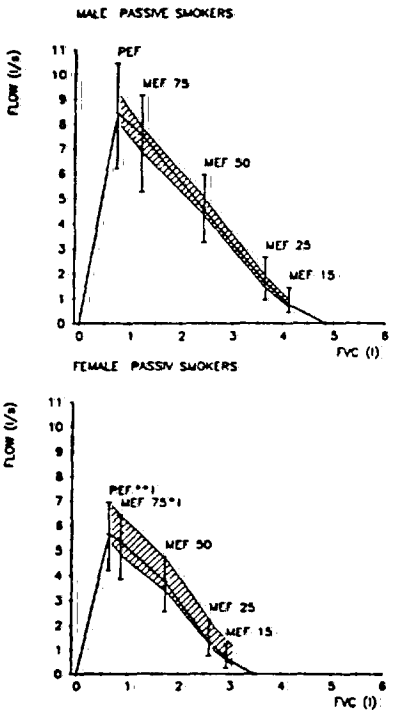

Fig. 3: MEFV-curves in male and female passive smokers

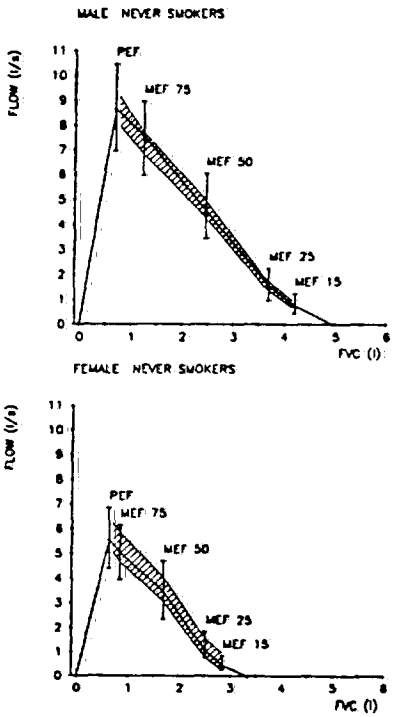

Fig. 4: MEFV-curves in male and female nonsmokers

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Passive smokers

Fig. 3 shows no disturbance in lung function for male passive smokers. In women PEF and MEF 75 still lie within the normal confidence interval, but the statistical analysis reveals a reduction.

This finding is difficult to interpret. If these changes are to be attributed to passive smoke exposure, the results found for active smokers would lead us to expect a decrease in the other flow rates as well. A possible explanation for the isolated reduction of PEF in female PS might be the relatively high interindividual variability of the flow-volume curve. This may lead to accidental correlations.

Never smokers

As the NS group also represents the reference population, no statistically significant alterations of their values can be expected (fig. 4).

Findings by other authors

Up to now eight studies have been published on passive smoking and lung function in healthy adults (tab. 4). These are exclusively cross-section studies.

Only in two studies the flow-volume curves were determined besides recording the time-volume curves. Whilst Brunnekreef et al. (6) found a statistically significant reduction of PEF and MEF 75 in PS in comparison to NS, Schilling et al. (42) were unable to establish such a relationship for any lung function parameter.

The remaining six studies which concentrated only on the time-volume curve did not show uniform results. Whereas three investigations confirm a reduction of lung function due to passive smoking (23, 38, 58), this relationship was not supported by the other three studies (11, 19, 27).

These investigations differ considerably in the methods applied. This discrepancies are mainly found in formation of subgroups, lung function pro-

AUTHORS	SUBGROUPS (n)*	PULMONARY FUNCTION PARAMETERS	RESULTS
SCHILLING ET AL. (1977) (42)	n NS, F NS (138); n NS, F CS (90); n CS, F NS (74); n CS, F CS (78)	FVC, FEV_1; PEF, MEF 50, MEF 25	NO STATISTICALLY SIGNIFICANT REDUCTION OF LUNG FUNCTION IN PS/H.
WHITE AND FROEB (1980) (58)	n NS (200), F NS (200) n PS/H (200), F PS/H (200) n CS (650), F CS (650)	FVC, FEV_1; FEF 25-75, FEF 75-85	FEF 25-75 AND FEF 75-85 IN NF PS/H SHOW STATISTICALLY SIGNIFICANT LOWER VALUES THAN IN NS.
COMSTOCK ET AL. (1981) (11)	n PS/H (369), F PS/H (69) n ES (179), F ES (37) n CS (672), F CS (142)	FEV_1, FEV_1/FVC	NO STATISTICALLY SIGNIFICANT REDUCTION OF LUNG FUNCTION IN NF PS/H.
HELSING ET AL. (1982) (19)	NF NS (373) NF PS/H (189)	FEV_1, FEV_1/FVC	THE PRESENCE OF POOR VENTILATORY FUNCTION IN PS/H SHOWED ONLY A VERY WEAK ASSOCIATION (R=0.1)
PETROVIC ET AL. (1982) (38)	n NS/H, PS/H (434) F NS/H, PS/H (741)	FEV_1/VC	STATISTICALLY SIGNIFICANT DIFFERENCES BETWEEN THE GROUPS (EXACT STUDY DESIGN WAS NOT AVAILABLE).
ZANFFRAN ET AL. (1983) (23)	n NS (849), F NS (826) n PS/H (65), F PS/H (1158)	FVC, FEV_1, PEF 25-75	IN THE COMPARISON OF NS AND PS/H AGED 40 YEARS OR MORE STATISTICALLY SIGNIFICANT DECREASE APPEARED IN MEN FOR FEV_1 AND PEF 25-75.
HEINRICH ET AL. (1984) (27)	n NS (342), F NS (86) n PS/H (39), M (365), NF (36) F PS/H (18), M (651), NF (36) n CS (303), F ES (59) M CS (247), F CS (153)	FVC, PEF 75-75 PEF 75-85	NO STATISTICALLY SIGNIFICANT REDUCTION OF LUNG FUNCTION IN NF PS/H, M, NF.
BRUNNEKREEF ET AL. (1985) (6)	F NS (30, 36) F PS/H (27, 39)	FVC, FEV_1; FVC, PEF, MEF 75, MEF 50, MEF 25, MMEF	PEF AND MEF 75 WERE STATISTICALLY SIGNIFICANT DECREASED IN F PS/H.

* M = NF NONS; M = NF NONSMOKER.
n = MALE; F = FEMALE.
OTHER ABBREVIATIONS SEE TEXT.

Tab.4: Review of literature published so far with regard to the topic pulmonary function in healthy adult passive smokers

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cedures, standardization and, moreover, age structure of the participants. Therefore, any direct comparison can only be limited.

The best way to compare them is by calculating the differences in lung function parameters between NS or normal persons on the one hand and in PS on the other. The data available can be seen in tab. 5. In female PS flow decreases for PEF and MEF 75 between 10 to 16 % and 9 to 14 %, resp. were found. For both male and female PS, decreases in FEF 25 - 75 and FEF 75 - 85 can be calculated which are between 6 and 9 % or 5 and 15 %, resp.

Reductions of this magnitude in our investigations were only found in comparing with NS and CS. Thus in female CS PEF was decreased by 19 % and MEF 75 by 14 %. For FEF 75 - 85 reductions were between 8 and 18 % in CS (27).

BRUNNEKREEF ET AL. (1985)			
- NS vs. PS/H (AT PRESENT EXPOSED AGED 40 - 60 YEARS, ONLY WOMEN)	F PEF	0.75 L/s	(10 %)
	F MEF 75	0.58 L/s	(9 %)
- NS vs. PS/H (EXPOSED SINCE ABOUT 15 YEARS. AGED 40 - 60 YEARS , ONLY WOMEN)	F PEF	1.33 L/s	(16 %)
	F MEF 75	0.97 L/s	(14 %)
WHITE & FROEB (1980)			
- NORMAL PERSONS VS. PS/H	M FEF 25-75	0.20 L/s	(9 %)
	F FEF 25-75	0.19 L/s	(7 %)
	M FEF 75-85	0.05 L/s	(5 %)
	F FEF 75-85	0.12 L/s	(15 %)
KAUFFMANN ET AL. (1985)			
- NS vs. PS/H (AGED 40 YEARS OR MORE)	F FVC	0.09 L/s	(3 %)
	F FEV_1	0.09 L/s	(4 %)
	F FEF 25-75	0.17 L/s	(6 %)

Tab. 5: Differences of lung function parameters in non-smokers with statistically significant association between passive smoke exposure and lung function reduction.

This would mean that the strain put upon lung function impaired by passive smoking is comparable with that by active tobacco smoke inhalation. That this cannot in fact be the case is emphasized by estimating the doses of the most principal bronchial irritants found in tobacco smoke to which the passive smoker is exposed. At sedentary or easy physical work over an 8-hour workshift cigarette equivalents of between 0.04 and 8 cigarettes may be taken into account, depending on the substances measured (tab. 6). Especially with regard to the equivalent of 8 cigarettes concerning nitrogen oxides it has to be assumed that other sources than tobacco smoke have not been taken into account. The substantial deviation is due to the great variability of the external exposure. This depends primarily on the amount of tobacco smoke emission and the ventilation of the room (39) while the internal exposure is mainly determined by the ventilations of the lungs.

Taking cigarette equivalents into consideration, the effects of passive smoking on lung function found by White & Froeb (58), Kauffmann et al. (23) and Brunnekreef et al. (6) are too high. A positive confounder in these investigations might be that persons having pre-existing impairments of lung function or bronchial hyperreactivity never take up smoking (51, 55) and so are over-represented in the PS group.

Furthermore, the question arises to what extent the described impairments of lung function due to passive smoking are of pathophysiological relevance. In 1984, the American Thoracic Society (1) published a diagram

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PARTICULATE MATTER	
- RESPIRABLE PARTICULATES	0.0% - 0.2%
VOLATILE SUBSTANCES	
- NITROGEN OXIDES	CA. 8
- ACROLEIN	0.80 - 4.00
- FORMALDEHYDE	?
- AMMONIA	?

Tab. 6: Cigarette equivalents for passive smokers concerning respiratory membrane irritants (Henschler 1983)

showing the various degrees of damages to the respiratory system from air pollution, which demonstrates a wide transitional field between physiological and pathophysiological alterations (fig. 5). This applies particularly to lung function parameters (24).

In general it may be assumed that under normal everyday conditions passive smoke exposure does not induce relevant pathological changes of bronchopulmonary function in healthy adults in the sense of adverse effects.

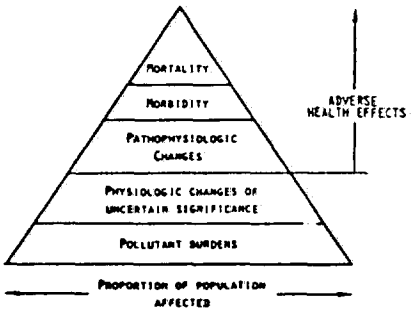

Fig. 5: Spectrum of biological response to pollutant exposure (American Thoracic Society 1984)

CONCLUSIONS

From the findings available so far there is no evidence that average everyday passive smoke exposure in the office or at home leads to an essential reduction of lung function in healthy adults.

Under unfavourable conditions (forced and passive smoke exposure over many years, small rooms, heavy physical work, prior illnesses of the respiratory system) a reduction in lung function due to passive smoking might be possible, particularly in women.

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